hydrogen, is heated for a long time in a good vacuum so as to expel the gas, its ionising power does not appear to be reduced. The ionisation apparently is not a definite function of the quantity of gas absorbed by the wire. The amount of hydrogen which a platinum wire will absorb at a low pressure is much greater than is usually suspected.

The results indicate that the increase in the negative ionisation is not caused by the hydrogen directly but rather by some change it produces in the surface of the platinum.

On the Electric Inductive Capacities of Dry Paper and of Solid Cellulose.

By Albert Campbell, B.A.

(From the National Physical Laboratory.)

Although dry paper is widely used as a supporting and insulating material in telephone cables, the published data with regard to its specific inductive capacity (or permittivity) appear to be very meagre. For this reason Mr. Gavey, C.B., Engineer-in-Chief of the Post Office, asked us to investigate the matter, and sent for test a large number of samples of paper obtained from four different cable manufacturers. All the samples consisted of what is known as " chemical wood paper," presumably free from lignified fibre. This type of paper, according to the Society of Arts Report on the Durability of Papers, is better in lasting quality than " mechanical wood paper " or paper made from straw, jute or esparto grass. Mr. Gavey, in addition, has kindly supplied the results of some tests on actual cables and further data for some of the samples of paper. This information is embodied in Part II of the present paper.

Part I.—Tests on Dry Paper.

One of the main difficulties in the testing of paper lies in the fact that it absorbs moisture so readily ; and the presence of moisture has a large effect on the specific inductive capacity and an enormous effect on the insulation-resistance. The nature of these effects is well illustrated by the curve in fig. 6 (Part II, p. 204), which shows how the capacity increases and the resistance decreases as a well-dried cable is allowed to absorb moisture from the atmosphere.

Methods of Testing.

In all cases small squares of the samples (each about 10×10 cm.) were dried in an electrically-heated oven, the mean temperature of which was kept at about 110° C. The dry paper was then made to form a part of the dielectric of a small plate condenser and the capacity of this was measured. Two distinctly different arrangements were used in forming the small condenser, and two series (A and B) of results were obtained. In the first method (A), the specimen to be tested was placed while still hot between indiarubber discs (of area 50 sq. cm.) covered with tinfoil also dry and warm. A weight of 15 kgm. was placed on the upper disc (being insulated from it) and the resulting condenser was tested as it cooled down. In method (B)* a small air condenser was formed from two well-trued circular brass surface plates (each of area 50 sq. cm.) placed horizontally and separated from one another to a distance of about 0·6 mm. by three very small accurately gauged distance-pieces of ebonite. This small condenser was kept in a desiccator, and out of this the leads were carried in an air-tight manner through ebonite tubes ringed with sulphur for better insulation. The capacity of the air condenser was first measured and then the dry sheet of paper was slipped between the plates, and the altered capacity was tested. From these measurements the specific inductive capacity (k) of the paper was deduced as follows :—

Let b = distance between the plates;

= $b_1 + b_2$, where b_1 and b_2 refer to air and paper respectively;

s = area of paper between plates.

Let K_1 and K_2 be the observed capacities. If K = capacity for area s with air only, then, neglecting edge action,

$$K = \frac{s}{4\pi b \times 900{,}000} \text{ mfds. and is thus known;} \qquad \text{let } K = \frac{a}{b}.$$

Now
$$K_1 = x + \frac{a}{b}, \quad \text{and} \quad K_2 = x + \frac{a}{b_1 + b_2/k}.$$

Let
$$Q = \frac{K_2 - x}{K_1 - x};$$

then
$$Q = \frac{b}{b_1 + b_2/k}, \quad \text{or} \quad k = \frac{b_1}{b/Q - b_1}.$$

Hence
$$k = \frac{K_2 - K_1 + K}{K b_2/b_1 - K_2 + K_1}. \qquad (1)$$

* This method was used by Mr. Packer, of the British Insulated Wire Company, in a series of paper tests made in 1901.

Measurement of Capacity.—The measurements of capacity were made by Maxwell's method,* the connections being shown in fig. 1.
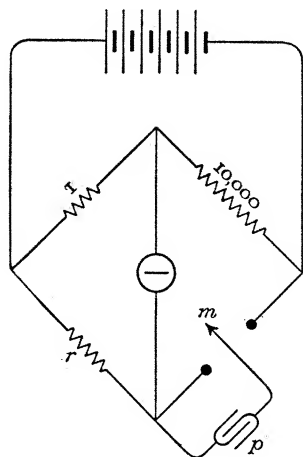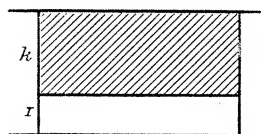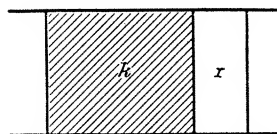

FIG. 1.

FIG. 2.

FIG. 3.

By a rotating contact-maker, the moving part of which is represented by m, the condenser p is charged and short-circuited with a frequency of n per second; during the charge only it forms one arm of the Wheatstone's bridge shown. A moving coil galvanometer of slow period is used, the resistance r is set so as to give nearly a balance, and then the speed of the contact maker is kept at such a value as to hold the light-spot at zero. The capacity was calculated by the usual formula, a deduction being made for the capacity of the commutator and leads (found by a blank experiment). The voltage used was about 40 volts.

Correction for Conduction.—In nearly every instance readings were taken with at least two frequencies (usually about 20 and 40 $\sim$ per second). Sometimes the apparent capacity was found to vary with the frequency, being greater at the lower frequency; this is due to conduction in the condenser, which behaves as a pure capacity shunted by a high resistance. When the conduction was not negligible, a correction for it was applied, the capacity and resistance being separated in the following way :—

Let K and R be the true capacity and resistance respectively; and let K_1 and K_2 be the apparent capacities for frequencies n_1 and n_2.

The commutator inserts the condenser in one arm of the bridge during a certain fraction of each revolution; let this fraction $= \sigma$. The value of σ may be obtained by measurements at the rim of the commutator.

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* As used by Professor J. J. Thomson, Mr. Searle, Dr. Glazebrook, and others.

We have $$\frac{\sigma}{n_1 R} + K = K_1, \quad \text{and} \quad \frac{\sigma}{n_2 R} + K = K_2.$$

Hence $$K = K_1 - \frac{n_2}{n_1 - n_2}(K_2 - K_1), \tag{2}$$

and $$R = \frac{n_1 - n_2}{n_1 n_2}\left(\frac{\sigma}{K_2 - K_1}\right). \tag{3}$$

In order to test these formulas, a condenser of capacity 1·011 mfd. (with high insulation) was shunted (*a*) by 100,000 ohms, (*b*) by 10,000 ohms, and the apparent capacity in each case was measured for two frequencies (about 14 and 38 ∿ per second). Case (*b*) was chosen as an extreme one, the apparent capacities rising to about 2·3 and 4·7 mfds. respectively. The values of K obtained by equation (3) from tests (*a*) and (*b*) were 1·020 and 1·009 mfd. respectively.

From (*a*), taking $R = 0.1$ megohm, σ was found by (4) to be 0·463, whilst measurements of the commutator gave $\sigma \doteqdot 0.446$. From the results of (*b*), using $\sigma = 0.463$, equation (4) gave $R = 0.00100$ megohm, agreeing with its known value. These results show that even in extreme cases the equations (2) and (3) may be used.

Test with Small Air Condenser.—The capacities which had to be measured were all very small, being from 0·0002 to 0·001 mfd., and the correction for the leads and commutator amounted to about 0·00001 mfd. Besides, no correction was applied for the edges of the plates,* which were without guard rims.

For these reasons the method was checked by applying it to test a small air condenser, the capacity of which was of the same order as the paper condensers to be tested. This air condenser was built up of two pieces of plate glass (each of about 100 sq. cm. area), silvered on the sides that faced one another, and separated by minute distance-pieces of ebonite or dry paper. The distance between the plates was from 0·03 to 0·05 cm., and was measured by gauging the distance-pieces. The conduction by surface leakage over the distance-pieces was relatively considerable, and had to be corrected for as described above. The values found by experiment were compared with those calculated from the measured dimensions, and the agreement was quite satisfactory, *e.g.*—

Calculated, mfd.	Observed, mfd.
0·000243	0·000244
0·000153	0·000153

* It appears that no complete mathematical treatment of the simple plate condenser has yet been carried out.

Measurement of Thickness.—The thickness of each sheet was tested immediately after the capacity measurements. As the surface of the paper presents much irregularity, it is a very difficult matter to find the average thickness. After several other arrangements had been tried, it was decided that an ordinary screw gauge was as good as any, and it was used throughout. The contact ends of this gauge had each an area of about 0·2 sq. cm., while the safety ratchet head applied a pressure of about 1 kgm. per square centimetre. As this pressure is about three times that applied to the indiarubber discs in method (A), it is probable that the increased compression will tend to make some allowance for the tinfoil penetrating the irregularities of the paper surface.

Results of Tests.—In Table I are given some of the results. A few of the samples were tested by method (A), both with a single sheet and with a pile of three sheets; the latter tests are included in the table.*

<div align="center">Table I.</div>

Sample number.	Approximate thickness.	Specific inductive capacity.		
		By tinfoil clamps.		By plate condenser.
		From 1 sheet.	From 3 sheets.	
14	mm. 0·08	2·5	2·6	
15	0·12	1·8	—	1·8
54	0·13	1·9	1·9	
49	0·18	2·1	2·2	
9	0·19	2·3	—	2·1
17	0·25	1·9	—	2·0
18	0·25	2·0	—	1·8
56	0·28	1·8	—	1·7
58	0·28	2·0	—	1·9
2	0·5	2·2	2·3	

From the foregoing table it will be seen that the two methods show as good agreement as could be expected from the nature of the material, but there is considerable variation from sample to sample. By weighing six samples it was found that their specific capacities were nearly in the order corresponding to that of their densities, which varied from 0·55 to 0·78. It was suggested that it would be of interest to compare the above values of specific inductive capacity with that for solid cellulose. As no data for the latter appeared available, a research (which forms the third part of this

* A sample of special black paper (partly parchmentised), kindly supplied by Mr. Clayton Beadle, gave $k \doteqdot 2·3$.

paper) was undertaken upon the electrical properties of solid cellulose Its specific inductive capacity was found to be about 6·8. Now, when the cellulose fibres (which we shall assume to form the whole solid part of the paper) are assembled with a certain amount of air space between them, the specific inductive capacity (k_p) of the resulting paper depends very largely upon the relative arrangement of the air and the cellulose. The following simple investigation will illustrate this point :—

Let d = density of cellulose (about 1·50), D = that of paper, 0 = that of air, q = ratio of cellulose volume to air volume.

Then
$$q = \frac{D_1}{d - D_1} = \frac{D_1}{1\cdot50 - D_1}, \tag{4}$$

and thus q can be found by experiment.

Now, for a given value of q, it will be found that k_p is least when the cellulose and air are in strata parallel to the condenser coatings, and greatest when these strata run at right angles to the coatings. These cases are represented sufficiently by figs. 2 and 3. Let k_1 and k_2 be the resulting specific inductive capacity in these cases respectively.

It is easy to show that
$$k_1 = \frac{(1+q)\,k}{q+k}, \tag{5}$$
and
$$k_2 = \frac{1+kq}{1+q}. \tag{6}$$

By weighing and gauging a number of the samples the value of q was found for each; from these values the minimum and maximum k_1 and k_2 were calculated. From Table II it will be seen that the actually observed values of k_p all lie below the mean of k_1 and k_2. This indicates (electrically) that the fibres of cellulose are arranged more in a direction parallel to the surfaces of the paper than at right angles to it, which is otherwise known to be the case.

Table II.

q.	k_1.	k_2.	$\frac{1}{2}(k_1+k_2)$.	Observed k_p.
0·577	1·45	3·12	2·28	1·93
0·629	1·49	3·23	2·36	1·89
0·843	1·64	3·65	2·70	2·21
0·930	1·70	3·79	2·75	2·25
1·078	1·79	4·02	2·90	2·30

It is clear that the law of mixtures found by L. Silberstein* does not apply here.

* 'Wied. Ann.,' vol. 56, p. 661, 1895.

Table II is of interest in connection with practical telephone work, in which the lowest possible value of the mean specific inductive capacity is aimed at. From the values of k_1 and k_2 we see that the mean resultant k depends very much on the relative positions of the paper fibres and the air spaces. The numbers in Table I give about 2·0 as a mean value for the specific inductive capacity of dry telephone paper, and this is in fair agreement with results already published by other observers. Signor E. Jona, by testing dry paper between metal plates, found k approximately equal to 2·0. Herr M. S. von Pirani* gives $k = 2\cdot0$ to 2·6, but he does not indicate clearly the conditions of his tests.

Part II (supplied by Mr. Gavey).—ADDITIONAL DATA AND TESTS ON CABLES

The undermentioned samples of oven-dried paper have been tested, with the results shown in Table III.

Table III.

Sample number.	Weight of ash, per cent.	Proportion by volume.	
		Fibre, per cent.	Air space, per cent.
9	1 ·37	49 ·0	51 ·0
15	1 ·45	35 ·0	65 ·0
17	1 ·80	36 ·0	64 ·0
18	1 ·11	36 ·5	63 ·5
56	0 ·96	32 ·5	67 ·5
58	1 ·70	36 ·0	64 ·0

The thickness of the papers was measured with a screw gauge which exerted a pressure of about 1·5 kgm. per square centimetre on the paper when the safety ratchet was used. It was found that the thickness of the paper measured with this pressure, and also with that of a light touch with the fingers on the screw gauge, differed by 10 per cent., *i.e.*, the air space figures given above would have been 6 per cent. higher if the ratchet were not used. It was also found that the thickness of the paper when several sheets were measured together was 2 to 3 per cent. less than when measured in single sheets.

The method finally adopted was to measure single sheets, using the ratchet referred to above, which it was thought would approximate as closely as was possible to the conditions observed by the National Physical Laboratory.

The figures used for the density of fibre and ash were 1·5 and 2·0

* 'Berlin Dissertation,' 1903.

respectively. From the weights per cubic centimetre and the respective densities, the volume of fibre and air space in each paper was calculated.

The samples of paper, although classed commercially as " Manilla " papers, on microscopic examination proved to be composed of mixtures of chemical wood pulp and hemp in different proportions. There was no trace of lignified fibres or mechanical wood. The minimum breaking stress specified by the Post Office for papers of this class is 4000 lbs. per square inch, but 7000 lbs. per square inch is about the average value obtained (*i.e.*, about 490 kgm. per square centimetre).*

With the kind assistance of Messrs. W. T. Henley's Telegraph Works Company, Limited, an attempt has been made to determine the effect of temperature on the electrical properties of the combination of air and dry paper as found in telephone cables. The results are indicated graphically in the curves in figs. 4 and 5, showing the variation of insulation-resistance and capacity respectively with temperature.
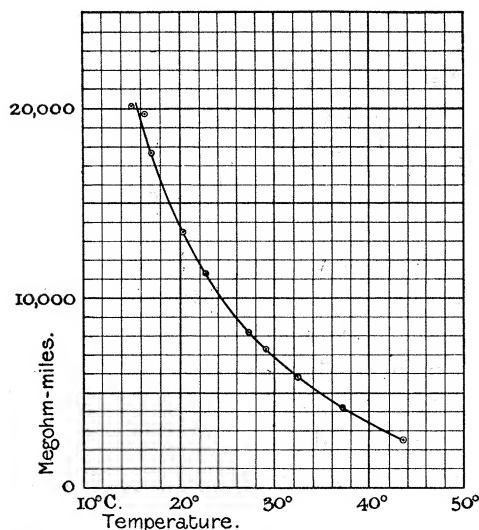

FIG. 4.—Variation of Insulation-Resistance with Temperature in Air Space Paper Core Cable (P.O.).
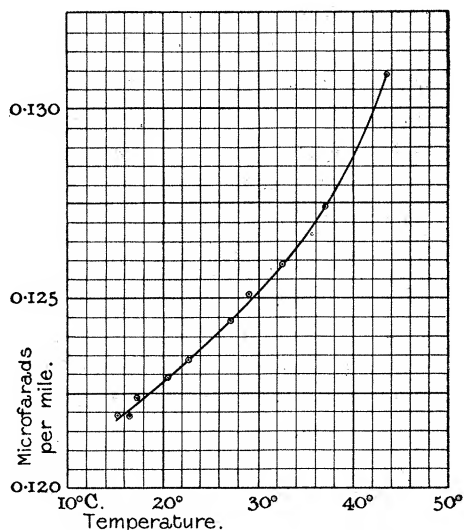
FIG. 5.—Variation of Capacity with Temperature in Air Space Screened Cable (Post Office Type).

* The construction of a paper-screened telephone cable is as follows :—The conducting wires are wrapped loosely in longitudinal (not spiral) strips of thin paper : two or more wires thus covered are placed together and thoroughly dried in an oven. While they are still dry and warm, a covering of lead is applied by a lead press, and in this way the moisture from the outside air is excluded. The paper merely acts as a mechanical separation between the conductors (and the lead sheath). As the lowest possible electrical capacity is desirable, anything that tends to decrease the permittivity of this separating medium is of practical advantage.

The proportion of air space and paper in the cable to which these tests refer was approximately 26 per cent. air, 74 per cent. paper.
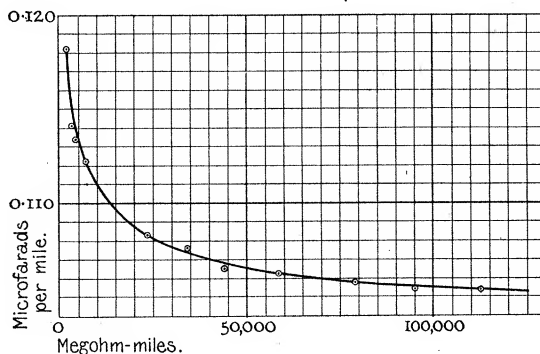

FIG. 6.—Variation of Capacity with Insulation-Resistance in Air Space Paper Screened Cable (Post Office Type).

The curve in fig. 6 was obtained with the kind assistance of the British Insulated and Helsby Cables, Limited, and shows the variation of capacity with the amount of uniformly distributed moisture in a cable as measured by the insulation-resistance. Each wire in this cable was insulated with paper and then covered with a copper tape wrapped on spirally. The cable was tested before being sheathed with lead, the copper tape making a sufficiently good earth.

The method adopted was as follows:—The cable was first dried and then allowed to stand exposed to the air for over a week. The moisture in the air penetrated through the interstices in the copper tape, making the paper damp, and tests were taken periodically to determine the capacity and insulation-resistance. The ends were kept well waxed and tests taken with and without a guard wire showed there was no leakage at the ends.

The proportion of air and paper in this cable was about 31 per cent. air, 69 per cent. paper.

The capacity in each case was measured by the comparison on a galvanometer of the charge deflection from the cable with that from a standard condenser. No correction has been applied for leakage, but the error was found to be about $1\frac{1}{2}$ per cent. on the capacity corresponding to 5000 megohm-miles, and $2\frac{1}{2}$ per cent. on the capacity corresponding to 2000 megohm-miles. This would reduce the alteration in the Temperature-Capacity Curve between the limits of temperature shown from $7\frac{1}{2}$ to 5 per cent.

It is suggested that the reason of the alteration in the capacity with increasing temperature may in some part be due to the absorption of the moisture in the paper by the hot air, thus altering the distribution of the

dielectrics in the cable. This view is somewhat borne out by the fact that another cable which was dried to an insulation-resistance of 140,000 megohm-miles, and therefore contained less moisture, has only 2 per cent. difference in the capacity between the same limits of temperature.

<div align="center">Part III.—Solid Cellulose.</div>

A series of tests were made on a number of samples of nearly pure cellulose kindly supplied to the laboratory by Mr. C. F. Cross.

The material was prepared by the following process:—Crude viscous 10-per-cent. solution of cellulose xanthogenic acid (sodium salt), with alkaline by-products, was spread on a glass plate, dried at 60° C., salted out with pure brine to remove soluble by-products, and the cellulose finally "fixed" and purified by treatment with acid and thorough washing.

The samples were in the form of fairly uniform translucent sheets from 0·06 to 0·3 mm. in thickness. For most of the experiments the sheets were dried for several days in an oven at 80° to 110° C. As the **air-dry** material is of the nature of a colloidal solution, the thorough drying is a long process, and the reabsorption of moisture from the atmosphere is very much slower than in the case of fibrous cellulose like paper. In the first experiments clamps of indiarubber and tinfoil were used, but it was found that these did not make satisfactory contact with the very smooth surface of the cellulose; they were therefore discarded and were replaced by mercury clamps* consisting of troughs with indiarubber edges pressed against opposite sides of the sheet and filled with mercury. The clamps and the mercury were usually dried in the oven and applied while still hot, a set of tests being taken as the whole apparatus cooled down to the temperature of the room. Capacity tests made on mica sheets of two different thicknesses gave concordant results and so proved that the mercury contacts were satisfactory. The drying made the cellulose very brittle, but immersion in water restored it to the flexible condition. Some of the capacity measurements were made by Maxwell's method (as already described), but in order to avoid polarisation and minimise the effect of conduction the method† shown in fig. 7 was usually employed.

S is a small standard condenser, K the condenser to be tested, R_1 and R_2 variable resistances, while M is a telephone-plate sounder‡ (giving 800 $\sim$ per second), such as is sometimes used in place of an electric bell. The intermittent current from M gives, by means of the transformer T, an

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* See R. Appleyard, 'Proc. Phys. Soc.,' p. 724, vol. 19, December, 1905.
† Used by Nernst and others.
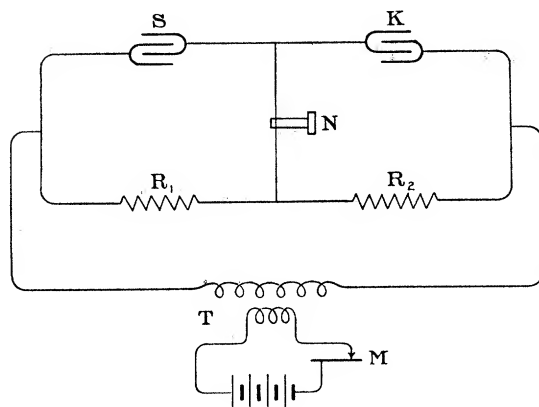‡ An "Electric Trumpet" supplied by The General Electric Company.

FIG. 7.

alternating current in the bridge SKR_2R_1. The ratio R_1/R_2 is altered until there is silence in the telephone N; then $K/S = R_1/R_2$. When the cellulose was thoroughly dry, the point of balance was quite definite, but when it was only air-dry, a point of minimum sound was all that could be obtained (but see below). The results obtained from sheets of different thicknesses (0·06 to 0·3 mm.) were in very fair agreement both for capacity and resistivity throughout a considerable range of temperature. The resistivities were measured by the method of direct deflection at 200 volts with 1 minute's electrification. Table III gives mean results for a range of temperature from 70° down to 20° C., and figs. 8 and 9 give the corresponding curves. (The resistivities with 2 minutes' electrification were 20 to 30 per cent. higher.)
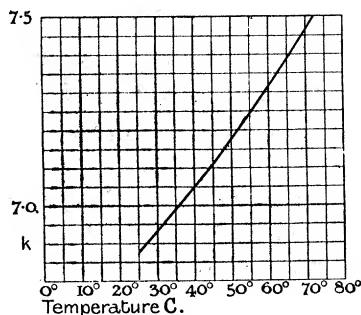

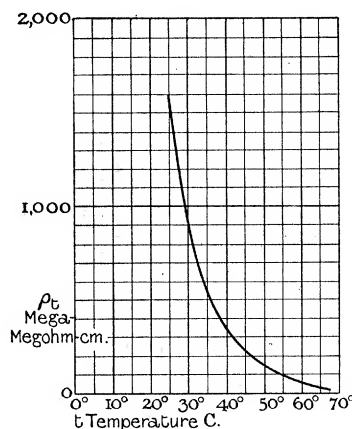FIG. 8.—Oven-dried Cellulose.
Specific Inductive Capacity.

FIG. 9.—Oven-dried Cellulose. Apparent
Resistivity by Direct Deflection Method.

Table IV.—Dry Cellulose.

Temperature.	Sp. ind. capacity.	Resistivity.
° C.		megohm-cm.
20	6·7	
25	—	1600×10^6
30	6·8	900×10^6
40	7·0	330×10^6
50	7·2	125×10^6
60	7·3	40×10^6
65	—	20×10^6
70	7·5	

Part IV.—Tests on Damp Cellulose.

The influence of moisture upon the electrical properties of paper (illustrated by the curve of fig. 6) is striking. Some years ago I observed that, when even a trace of moisture was present, a sudden lowering of the temperature always caused a considerable increase in insulation-resistance.*

At that time I advanced the theory that the effect was largely a mechanical one, the lowering of temperature causing the moisture to be drawn into the hollow tubular interiors of the fibres. Since the solid cellulose is not of fibrous structure, it was of interest to try its behaviour when in the "air-dry" condition, *i.e.*, after exposure to the atmosphere for a considerable time. Of course, the amount of moisture present depends on the humidity of the air, the temperature, etc., and therefore the conditions vary from day to day; thus the results refer only to the actual conditions holding at the time of the particular experiment. In each case the cellulose was placed between the clamps, hot mercury was poured in, and observations were made during the cooling. Tests of apparent resistivity were made by observing the current due to a constant potential difference kept continuously applied. Fig. 10 gives an example of a curve thus obtained. As might be expected, strong polarisation effects made their appearance. When attempts were made to measure the capacity by Maxwell's method the polarisation caused a large displacement of zero, and made it impossible to obtain any true result. With the telephone method of fig. 7 the relatively good conductance of the specimen made it impossible to obtain a balance. However, by shunting the standard condenser S (as shown in fig. 11) by a variable resistance X, it was always possible to get a good balance.

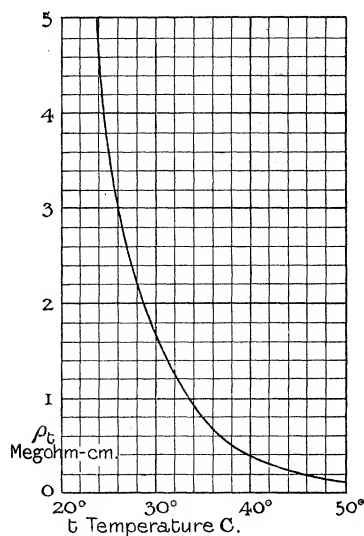* See E. H. Rayner, 'Proc. Inst. Elec. Eng.,' p. 625, vol. 34 1905.

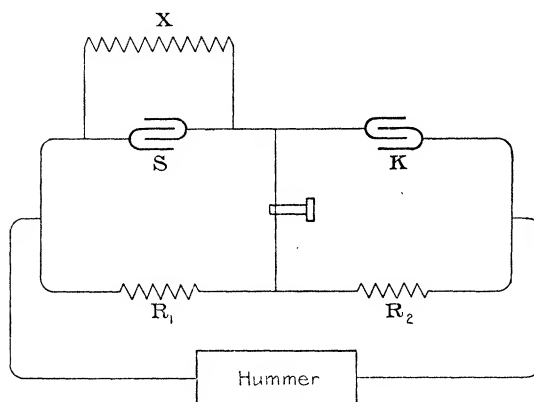Fɪɢ. 10.—Air-dry Cellulose.   Apparent Resistivity by Direct Deflection Method.

Fɪɢ. 11.

As high frequency is desirable, the source of current was a microphone hummer* of special construction giving 2000 ∼ per second. The arrangement of this is shown in fig. 12. A is a rod of mild steel (or tool steel) supported horizontally at nodal points, and carrying at one end a very light microphone B shunted by a condenser C. T is a transformer whose secondary is connected to the coil of a polarised telephone magnet M. If A is set vibrating by a blow, the pulsating current in the microphone circuit gives an alternating current round M, and so maintains the vibration.

* For earlier microphone hummers see the following :—R. Appleyard, 'Elec. Review, pp. 57 and 656, vol. 26, 1890 ; J. E. Taylor, 'Inst. of Elec. Engs.,' p. 396, vol. 31, 1901 ; and F. Dolezalek, 'Zeitschr. für Instrumentenkunde,' p. 240, August, 1903.

The testing current is taken from another secondary winding of T. A mild-steel rod 2·5 cm. in diameter and 23·7 cm. long gives 2000 ∿ per second. By using a shorter rod a frequency of 3000 to 4000 can be attained.
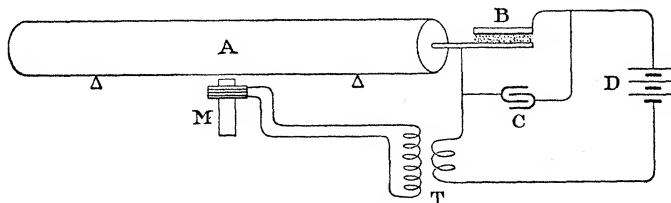

FIG. 12.—Microphone Hummer for 2000 ∿ per second.

When the telephone is silent $K/S = R_1/R_2 = X$ divided by insulation resistance of K.

In fig. 13 is shown the variation of capacity with temperature for a sample of air-dry cellulose, suddenly heated and allowed to cool slowly.
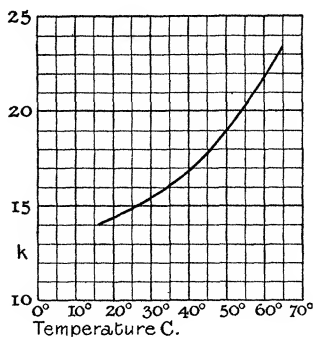

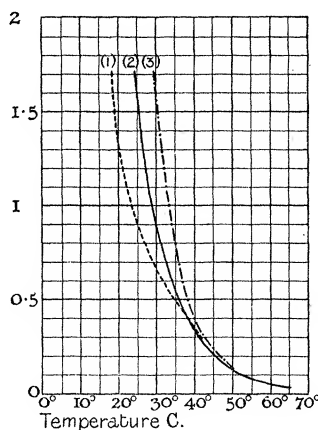
FIG. 13.—Air-dry Cellulose. Sp. Inductive Capacity.

FIG. 14.—(1) Cable, (2) Oven-dried Cellulose, (3) Air-dry Cellulose.

From the values of the shunt X required to give a balance, the values of the insulation resistivity of K at the various temperatures can be obtained. Measurements made with the high frequency ($n = 2000 \sim$ per second) at room temperatures gave values of the resistivity about 10 times smaller than the apparent resistivity shown by the steady deflection method (as in fig. 10); the variation with temperature was also much less with the high frequency alternating current. It may be mentioned that in the direct deflection test the immediate deflection fell off 10 to 15 per cent. after 1 minute's electrification. In telephone work the frequencies are high, and therefore it is the lower values of the resistivity that would occur when leakage due to moisture happens.

The matter, however, seems to want further investigation.

It will be seen from fig. 13 that when air-dry cellulose is quickly heated the specific inductive capacity increases very considerably. If the raised temperature is maintained and the moisture allowed to escape, the capacity gradually falls to a value dependent on the temperature. Since the material is not porous in the same sense that paper is, the mechanical theory based on the tubular nature of the fibres is thus excluded. The observed facts seem to indicate that a part of the moisture is chemically combined with the cellulose, the whole forming an electrolytic solution (possibly of water in cellulose hydrate). When the temperature is raised, partial *dissociation* appears to occur and, with continued steady temperature, dissociation equilibrium is attained. High specific inductive capacity and low resistivity would thus correspond to the presence of a relatively large amount of dissociated moisture present throughout the material.

Dielectric Strength of Solid Cellulose.—A number of sheets of cellulose, from 0·06 to 0·3 mm. thick, were tested for break-down voltage, both air-dry and oven-dried specimens being tried. The apparent dielectric strength (*i.e.*, $V_{max.}$ divided by thickness in centimetres) varied with the thickness of the sheet; for air-dry cellulose it was of the order of 250,000 volts per centimetre, and for oven-dried material 500,000 volts per centimetre.

Cellulose Acetate.—As cellulose acetate is coming into common use as an insulating material for covering thin wires, its electrical properties are of practical interest. It was therefore thought desirable to make a few tests upon it with a view to comparing its properties with those of cellulose. The acetate is soluble in chloroform, and by pouring the solution on to a glass plate a smooth and tough film may be obtained. Two specimens were tested namely :—

(*a*) Normal tri-acetate (kindly supplied by Mr. C. F. Cross).

(*b*) A sample from a German source, said to contain both tri- and tetra-acetate; it was found to contain also a small amount of sulphur in combination, probably SO_4H residue. By more recent methods of acetylation these products are more economically obtained: the acetylizing mixtures contain sulphuric acid, and a proportion of SO_4H residues is fixed together with the acetyl.

Sample (*a*) when air-dry gave a specific inductive capacity of about 4·7 ; when oven-dried the value was about 3·9. The variation with temperature was scarcely perceptible, being of the order of one per cent. for 40° C. Sample (*b*) gave less consistent and somewhat higher values.

The resistivities were also determined approximately, the result at 200 volts with one minute's electrification being given in Table V.

Table V.

Material.	Condition.	Temperature.	Resistivity.
		° C.	Mega-megohm-cm.
Cellulose acetate (*a*)......	Air-dry	16 ·5	200
,, ,, ...	Oven-dried	26 ·0	over 9000
Cellulose acetate (*b*)......	Air-dry	26 ·0	13
,, ,, ...	Oven-dried	26 ·0	121

General Remarks.—On comparing the temperature-capacity curves for the cable and the dry cellulose sheet, it will be found that the rate of variation of capacity with temperature is about 50 per cent. greater in the cable than in the sheet; this indicates probably that the paper of the cable was not dried to such an extreme extent as the cellulose sheet. The air-dry cellulose, on the other hand, has a very much larger k to start with and this increases very rapidly with temperature (if the moisture be kept from escaping).

With regard to the resistivities, the curves of figs. 4, 9, and 10 have been brought together in fig. 14 (by altering the scales) so as nearly to coincide at 40° C. It will be noticed that between 30° and 40° C. the cable shows the least, and the air-dry cellulose the greatest variation with temperature. This is probably due to the fact that in the cable the moisture can partially escape into the air spaces. It is curious to find, for the dried cellulose, that while the capacity does not alter much with temperature, the insulation alters enormously. This leads to the inference that in spite of the extreme drying (to brittleness) the alterations with temperature are still due to dissociation of combined moisture. The amount of this moisture may be very infinitesimal when we remember that the drying raises the resistivity 300 million times. With regard to the cellulose acetate, even in its air-dry condition it is a good insulator. Its specific inductive capacity also is lower than that of cellulose. It is evident, therefore, that it is far less susceptible to the effects of moisture than either paper or solid cellulose.